

1.1 Field Lines



Figure C1.3: Lightning travels across the sky at speeds of over 100 km/s.

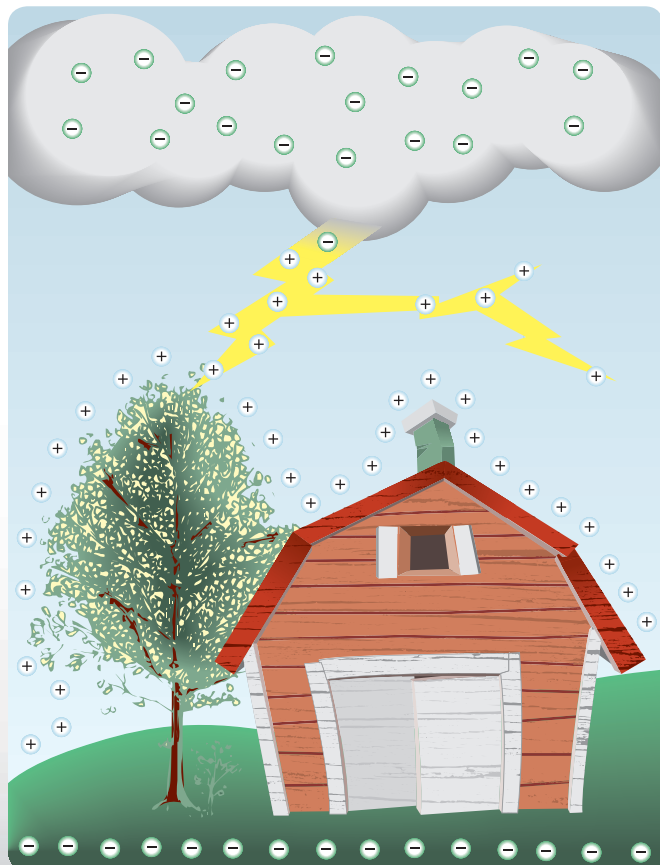
Think back to the last time you saw a sky like this. Can you remember what the weather was like that day? At first, this may seem like a ridiculous question, but it is not coincidence that most thunderstorms occur late in the afternoon or evening of a very hot, humid summer day. The reason for this is that it takes the intense summer sun to make the air hot and rich in water vapour. Warm air floats up in cooler surrounding air—like a cork in water. As it rises, the water vapour starts to condense and forms a cloud. The condensation releases energy, which causes the air parcel to get even warmer and rise even higher. Sometimes the top of a thundercloud can reach 12–20 km above the ground!

As a column of warm water vapour rushes up, it comes in contact with a column of condensed water droplets that are descending. Since the water droplets more readily hold on to their electrons than the rising water vapour does, electrons are transferred from the rising water vapour to the descending water droplets. The result is that the bottom of the cloud has an excess of electrons, so it is **negatively charged**. The top of the cloud has lost electrons, so it is **positively charged**. Recall from previous courses that objects with opposite charges attract each other, while objects that have the same type of charge repel one another.

- ▶ **negatively charged:** having more electrons than protons, creating an imbalance
- ▶ **positively charged:** having fewer electrons than protons, creating an imbalance



As the cloud passes over buildings and other tall objects on the ground, how will the electrons in these objects respond? Since like charges repel, the electrons within the objects on the ground are forced to move away from the cloud. The presence of the large negative charge at the bottom of the cloud, in turn, causes the separation of charges on Earth's surface—the surface becomes positively charged and below the surface becomes negatively charged. Finally, pockets of ionized air molecules in the atmosphere can form a conductive path for the electrons in the cloud to jump to the large, positive surface of Earth, resulting in a lightning strike.



DID YOU KNOW?

The average thunderstorm releases the same amount of energy as a 20-kilotonne nuclear weapon.



The reason that a lightning strike can be so dangerous is because the number of electrons transferred is huge—around 10^{18} to 10^{20} electrons. To make it easier to describe and study these effects, scientists use a special unit for charge called the **coulomb**, named after Charles Coulomb, one of the first researchers in the study of electricity. The symbol for this unit is C. One coulomb is equivalent to the transfer of 6.25×10^{18} electrons. If one object gains this number of electrons, it is said to have a charge of -1.00 C; and if a second object loses this many electrons, it is said to have a charge of $+1.00$ C. Since the symbol for charge is q , this would be communicated as follows:

charge on object 1 = $q_1 = -1.00$ C

charge on object 2 = $q_2 = +1.00$ C

The quantity of charge that you normally encounter is much less than one coulomb.

coulomb:
an SI unit for charge; one coulomb is equivalent to the transfer of 6.25×10^{18} electrons

Example Problem 1.1

If you scuff your feet while walking across a carpet on a dry day, you can acquire a charge of $-55 \mu\text{C}$.

- Use the charge to determine whether you gained or lost electrons.
- Explain why is it essential for another object to have a charge of $+55 \mu\text{C}$. Identify this object.
- Use the fact that $1.00 \text{ C} = 6.25 \times 10^{18}$ electrons to set up a conversion factor that would enable you to determine the number of electrons gained or lost while scuffing your feet.



Solution

- The negative sign on the charge indicates that you gained electrons.
- Electrons cannot be created nor destroyed; so, if you gained electrons, something else must have lost them. In this case, the carpet must have lost a number of electrons equivalent to a charge of $+55 \mu\text{C}$.
- step 1:** Set up a conversion factor.

$$1.00 \text{ C} = 6.25 \times 10^{18} \text{ electrons}$$

$$\text{Therefore, } 1 = \frac{6.25 \times 10^{18} \text{ electrons}}{1.00 \text{ C}}$$

To convert from coulombs to electrons in the next step, coulombs are placed in the denominator.

step 2: Convert from coulombs to number of electrons.

$$\begin{aligned} \text{charge on the person, } q_{\text{person}} &= 55 \mu\text{C} \\ &= 55 \times 10^{-6} \text{ C} \times \frac{6.25 \times 10^{18} \text{ electrons}}{1.00 \text{ C}} \\ &= 3.4 \times 10^{14} \text{ electrons} \end{aligned}$$

While scuffing your feet across the carpet, you would gain 3.4×10^{14} electrons.

Practice

- Pockets of ionized air in the atmosphere are not evenly spaced; instead, they tend to be randomly distributed. Use this information to explain why lightning strikes tend to have a jagged appearance instead of being perfectly straight.
- It's been said that humidity is the fuel of a thunderstorm. The higher the humidity, the greater the possibility of having a large-scale storm.
 - Explain why an updraft within a thundercloud will tend to rise higher if the air has a higher moisture content.
 - Explain the role of the air's moisture content in producing the positive and negative charges within a thundercloud.
- While completing the "Observing Magnetic and Electrical Effects" activity in the beginning of the chapter, a student rubbed an ebonite rod with fur, transferring about 1.4×10^{10} electrons from the fur to the ebonite rod.
 - Determine whether the ebonite rod has a negative or positive charge.
 - Use a conversion factor to determine the charge (in coulombs) on the ebonite rod.

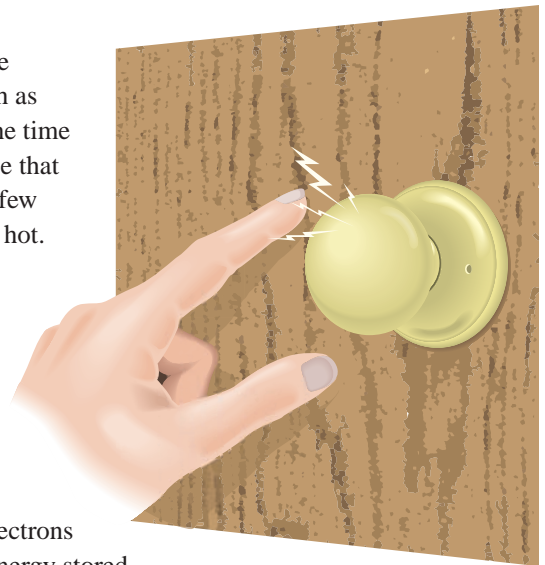
Voltage

As shown in Example Problem 1.1, your body can acquire a charge from the environment. This frequently happens as one object slides past another, such as when you scuff your feet across a carpet and reach out to open a door. By the time you reach the other side of the room, you may have acquired so much charge that when you get very close to the doorknob, the excess charge jumps across a few millimetres of air, creating a spark. This can be painful because the spark is hot. There clearly is energy involved here.

work done moving electrons from carpet to your body = potential energy stored in the excess electrons on your body = energy transferred through your fingertip in a spark

Prior to touching the doorknob, work was done removing electrons from the carpet, causing the electrons to gain potential energy relative to other objects, such as the doorknob at the other end of the room. Since the doorknob is a **conductor**, as soon as your hand gets close enough for the electrons to jump the tiny air gap, a spark is produced. In other words, the potential energy stored in the electrons is converted mostly to thermal energy, which causes the pain in your finger, and partially to light and sound energy as the spark produces a tiny flash and a snapping sound.

Measuring this energy is a challenge because it is transferred through the action of electrons, and the sheer number of electrons is huge. One approach to this problem is to describe the energy transfer in terms of the change in electric potential energy per unit of charge, or the **electric potential difference**. The unit for electric potential difference is the unit for energy, the joule, divided by the unit for charge, the coulomb. This combination has been given a special name, the **volt**. In everyday speech, many people use the unit to identify the quantity, so they simply refer to electric potential difference as **voltage**.



$$\text{voltage or electric potential difference} \rightarrow V = \frac{\Delta E_p}{q}$$

change in electric potential energy

charge

$$\text{Units: } 1 \text{ volt} = \frac{1 \text{ joule}}{\text{coulomb}}$$

$$1 \text{ V} = 1 \text{ J/C}$$

- ▶ **conductor:** a material in which some of the electrons can move freely, allowing the material to conduct an electric current
- ▶ **electric potential difference:** the change in potential energy per unit of charge
- ▶ **volt:** the unit for electric potential difference; $1 \text{ V} = 1 \text{ J/C}$
- ▶ **voltage:** another term for *electric potential difference*

Example Problem 1.2

While scuffing your feet across the carpet, you do about 0.25 J of work to acquire $-55 \mu\text{C}$ of charge. Determine your voltage.

Solution

$$\begin{aligned} \Delta E_p &= W & V &= \frac{\Delta E_p}{q} \\ &= 0.25 \text{ J} & & \\ q &= -55 \mu\text{C} & & \\ &= -55 \times 10^{-6} \text{ C} & & \\ V &= ? & & \end{aligned}$$

$$\begin{aligned} &= \frac{0.25 \text{ J}}{55 \times 10^{-6} \text{ C}} & \leftarrow \text{The sign of the charge is not included.} \\ &= 4.5 \times 10^3 \text{ J/C} \\ &= 4.5 \times 10^3 \text{ V} \end{aligned}$$

After scuffing your feet across the floor, your voltage is $4.5 \times 10^3 \text{ V}$.

Example Problem 1.3

An appliance in your kitchen is plugged into a socket that can provide the appliance with 120 V and up to 15 C of charge every second. If the cord for this appliance became frayed and you grabbed it with wet hands, calculate the energy that could be transferred to you in 1 s.

Solution

$$\begin{aligned} V &= 120 \text{ V} & V &= \frac{\Delta E_p}{q} \\ q &= 15 \text{ C} & \Delta E_p &= Vq \\ \Delta E_p &= ? & & \\ & & &= (120 \text{ V})(15 \text{ C}) \\ & & &= (120 \text{ J/C})(15 \text{ C}) \\ & & &= 1.8 \text{ kJ} \end{aligned}$$

The energy that could be transferred to you in 1 s is 1.8 kJ—a dangerous quantity that could be lethal.

The Combination of Energy and Charge



Voltage is probably the one quantity of electricity people are most familiar with. Many portable devices are powered by cells that are rated at 1.5 V. What exactly does that value mean? For most students, the best answer comes from translating the units:

1.5 V means 1.5 J of electric potential energy per coulomb. If you apply this same thinking to the results of Example Problem 1.2, the results might seem a little alarming: 4.5×10^3 V means 4500 J/C. Isn't this a high value? If there was a sign on the doorknob that said "4500 V," would you still touch it?



The important thing to remember is that voltage indicates the joules of energy transferred by every coulomb of charge. So, if you don't have many coulombs of charge, the total energy transferred may not be a very big concern. If the sign on the door said "0.25 J," you may be much less concerned. However, if the number of coulombs involved is very large, you have to be especially careful. In Example Problem 1.3, the appliance's frayed cord was connected to a 120-V source, which at first might appear to be much safer than the 4500 V between you and the doorknob. However, since the number of coulombs involved is much larger, the energy that can be delivered is actually much greater. A lightning strike can be extremely dangerous because both the voltage and the quantity of charge involved are large.

Practice

4. A lightning strike transferred about 15 C of charge from a cloud to a building. The voltage between the cloud and the building was 1.50×10^8 V.
 - a. Calculate the energy delivered in the lightning strike.
 - b. A typical home in Alberta uses 3×10^9 J of electrical energy every month. Compare your answer to question 4.a. with this value.



Hiking Through Fields

People who enjoy outdoor activities, like hiking, camping, and rock climbing, have to pay close attention to the conditions in their environment. Much of the data from the environment is easily observable, such as the types of cloud formations and the temperature. Other factors, such as changes in humidity or atmospheric pressure, require special instruments in order to be observed. In this section you will learn about three aspects of the environment that can only be observed indirectly through their effects on other objects.



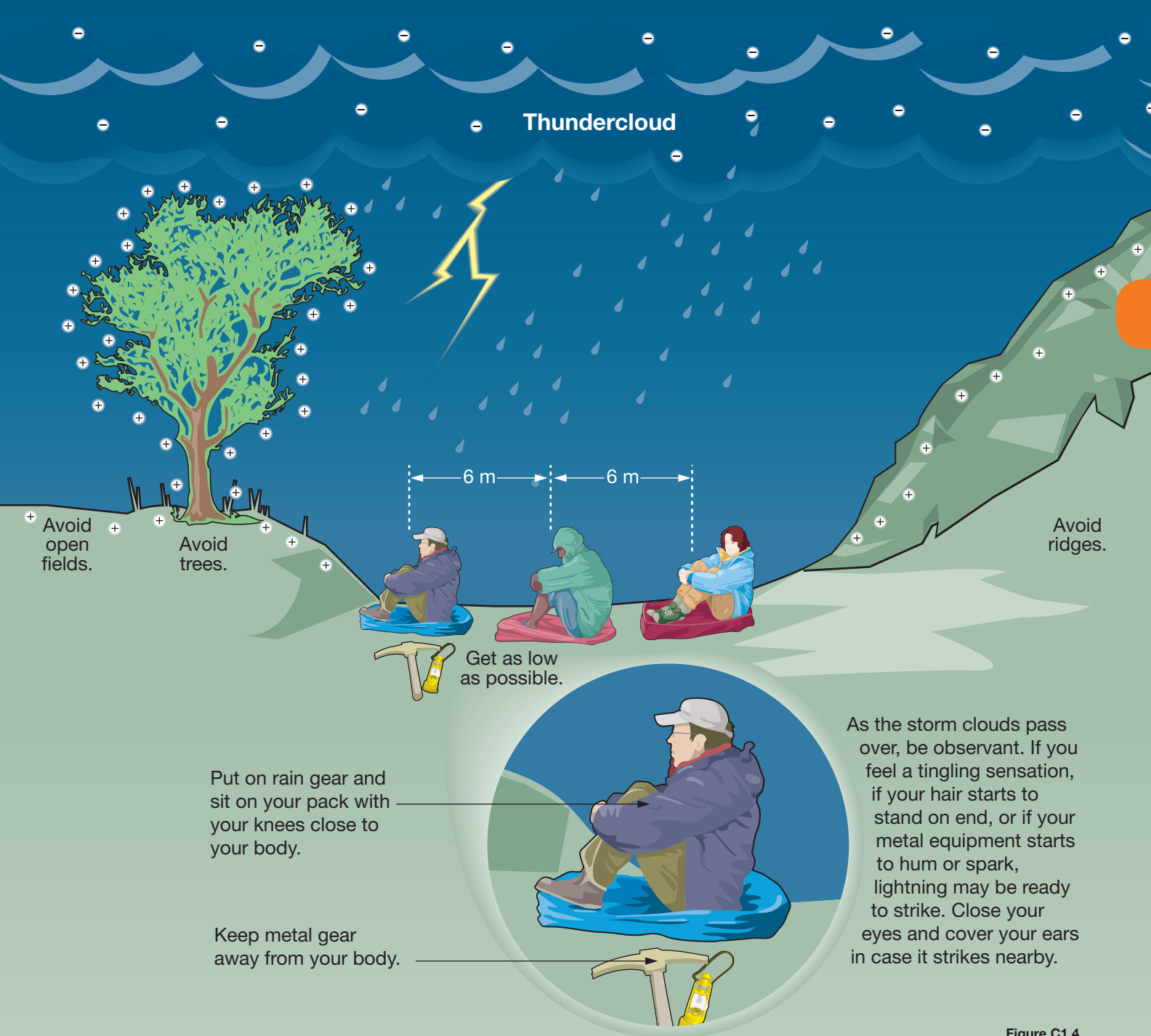


Figure C1.4

The Electric Field

Hikers and rock climbers have to be especially careful of the potential hazards presented by thunderstorms. If you are in a forested area, the dense cover of trees can make it very difficult to see the sky and watch for approaching clouds. Thunder can echo through canyons, making it very difficult to know the direction a storm is approaching from. If you are in steep terrain, storm clouds can suddenly blow overhead from a nearby ridge, giving you only minutes' notice that a storm is approaching. If you were hiking in the mountains and were surprised by a thunderstorm's sudden approach, what would you do?

The suggestions shown in Figure C1.4 are the recommended preventative measures to avoid being hit by lightning. Note the list of things to watch for. The thundercloud may be several kilometres above you, yet the huge negative charge on the bottom of the cloud is still capable of making your skin tingle, your hair stand on end, or your metal equipment hum and spark. All this can occur before the lightning strikes. How is the cloud, which may be thousands of metres above the ground, able to exert forces on objects on the ground below? A meteorologist would answer this question by saying that the charge on the bottom of the cloud is surrounded by an **electric field**. The three hikers cannot see the electric field itself because it is invisible. They can only observe the effects that the field has on charges within the field.

▶ **electric field:** a property of the space around a source charge that enables the source charge to exert forces on other charges that enter this region

For example, one of the hikers might notice that loose threads on a frayed part of a jacket are starting to stand on end. Even though the threads are **insulators**, and cannot pass an electric current, the charge within the threads can be rearranged so that the threads respond to the electric field. The threads are not the electric field, but rather they provide evidence that the field is present. Since a thread provides a way of testing if a field is present, it is called a **test body**. Test bodies are observable objects that experience a force due to the presence of a field. Other test bodies in this situation could include the hair on the hiker's head or the ions within nerve endings that produce a tingling sensation in the hiker's skin.

Thunderclouds are not the only sources of electric fields. In general, any charged object will surround itself with an electric field. A tiny circuit charges the wires in a portable bug zapper, shown in Figure C1.6, to create a strong electric field close to the wire mesh. This field is then used to exert lethal forces on insects that are close to the mesh grid.



Figure C1.5: The charges within the fibres of the threads shift slightly, allowing the threads to respond to the electric field.

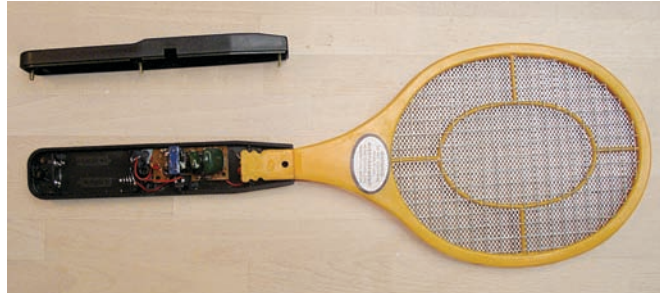


Figure C1.6: Bug zappers use strong electric fields.

- ▶ **insulator:** a material in which none of the electrons can move freely, preventing the material from being able to conduct an electric current
- ▶ **test body:** an observable object that can experience a force due to the presence of a field

The Magnetic Field



If the hikers take all the recommended precautions, they could make it through the storm unharmed. The wind would soon carry away the thunderclouds and the massive charge that created the dangerous electric field. But this is not the end of the hikers' experience with fields. After taking off their rain gear, they might decide to resume their trek and check their bearings with a compass.

The compass needle soon swings around and indicates which direction is north. What exerts this force on the compass needle? If you look at the compass, you will see that there does not appear to be anything touching it other than the hiker's hand. The hand cannot be the source of the force because if the hiker holds the compass in the other hand or sets the compass on the ground, it still points the same way. What is the source of this force?

A geologist would say that Earth's **magnetic field** exerts the force on the compass needle. Once again, you cannot see the magnetic field itself—it's invisible. You can only observe the effects of the magnetic field on the appropriate test body (in this case, the tiny magnet that forms the compass needle).

- ▶ **magnetic field:** a property of the space around a magnet or an electric current that enables the magnet or electric current to exert forces on other magnets, such as compass needles, and electric currents that enter this region



Earth's magnetic field is thought to originate from electric currents deep within the planet. In general, magnetic fields are produced by electric currents and magnets. This is why compass needles may not function properly close to electric motors or speakers. These devices produce their own magnetic fields that can interfere with the compass's ability to align itself with Earth's magnetic field.



The Gravitational Field

Rock climbing is an outdoor activity that requires specialized equipment, skills, and careful training. Once these things are in place, the only other requirement is a safe and interesting place to climb. As climbers inch up a rock face, they move themselves farther from the centre of Earth, overcoming the force of gravity the whole way up.



DID YOU KNOW?

Archaeologists suspect the first compass originated in China thousands of years ago. The ancient Chinese compasses used a piece of iron oxide, $\text{Fe}_3\text{O}_4(\text{s})$, that happened to be naturally magnetized. Over time, the design was refined to use a small iron needle. Magnetic iron oxide was still needed to periodically remagnetize the smaller needle using a process similar to the one you used in the "Observing Magnetic and Electrical Effects" activity.



Figure C1.7: A traditional Chinese compass



The descent can be just as dangerous as the climb up. The tension in the rope is balancing the downward force of gravity as the climber descends. How is Earth able to exert such a large force on the climber? If the contact with the rope supplies the upward force, what is the contact with the planet that supplies the downward force?

The contact between Earth and the climber is the **gravitational field** of Earth that pulls the climber toward Earth's centre. Just like electric and magnetic fields, the gravitational field of Earth is invisible—it can only be observed through the forces that it exerts on test bodies. The test bodies for gravitational fields are other objects with mass. Examples would include the climber, a penny in the climber's pocket, or even a satellite in orbit hundreds of kilometres above the climber. Earth exerts a gravitational force on each of these masses through the gravitational field that surrounds the planet.

▶ **gravitational field:** a property of the space around a source mass that enables the source mass to exert forces on other masses that enter this region

▶ **field lines:** lines that describe the direction of a field by the way they point, and the strength of a field by their density

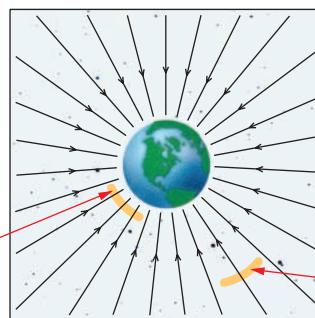
Although Earth's gravitational field is invisible, it can be represented by **field lines**. The field lines point in the direction that a test mass would be forced if it were brought close to Earth—toward the centre of the planet. The density of the field lines communicates the strength of the gravitational field. Close to the surface, the field lines are highly concentrated, indicating that the field is stronger than it is farther from the planet, where the field lines are farther apart. Field-line diagrams are useful because they can communicate the overall pattern and shape of the field.

Earth is not the only object that surrounds itself with a gravitational field. The Moon, the other planets, and the Sun each have their own gravitational field. In general, any object with mass will be surrounded by a gravitational field; however, only very massive objects, like planets, produce gravitational fields with observable effects.

Image of Earth from Space with Gravitational Field Lines Added



Although Earth's gravitational field is present, it is invisible.



The lower concentration of field lines indicates that the field is weaker here.

The higher concentration of field lines indicates that the field is stronger here.



Practice

5. Although air is not normally a conductor of electricity, under the extreme circumstances of a thunderstorm, it can provide a conducting path for lightning. In general, lightning tends to follow a shorter path rather than a longer one.
 - a. Refer to Figure C1.4, on page 317 to explain why hikers should avoid open fields, trees, and ridges during a storm.
 - b. Explain the rationale for the recommended location and body position of the hikers.
6. In addition to magnetic fields, compass needles also respond to metals that contain iron, cobalt, and nickel. Refer to the concept of a magnetic field to explain why it is important to stand clear of these metals when determining which way is north.
7. The strength of Earth's gravitational field is slightly less at a mountain's peak than it is at the base of the same mountain. Refer to field lines as you explain this effect.
8. Copy and complete the following table. Leave enough room for your responses as you complete it.

Type of Field	General Description of Sources for This Field	General Description of Test Bodies for This Field	Two Examples of a Source for This Field
electric			
magnetic			
gravitational			

Describing Fields with Diagrams

The technique of describing a field with a field-line diagram does not just apply to gravitational fields. As you will see in the following investigations, this technique can also be used to describe electric fields and magnetic fields.

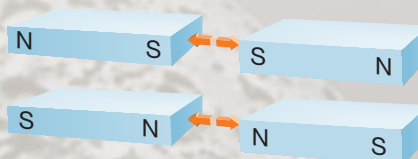
Before starting the investigation “Observing Magnetic Field Lines,” it is important to quickly review some fundamental ideas about magnets that you have learned in previous courses.

Properties of Magnets

Every magnet has two poles: north and south.



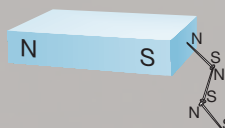
Like poles repel one another.



Opposite poles attract one another.



Some objects can become temporary magnets.



Investigation

Observing Magnetic Field Lines

Purpose

You will sketch the patterns produced by test bodies when they are placed in magnetic fields.

Materials

- ceramic or iron bar magnet
- iron filings in a container with a removable lid that allows the filings to be sprinkled
- compass
- lid of a shoebox with one end open
- cookie sheet that is ferromagnetic (A magnet will stick to it.)
- 2 books that are the same thickness (Both must be thicker than the bar magnet.)
- “Placement of a Compass Around a Bar Magnet” handout from the Science 30 Textbook CD



Part A: Using Iron Filings as Test Bodies

Procedure and Observations

step 1: Set up the apparatus as shown in Figure C1.8.

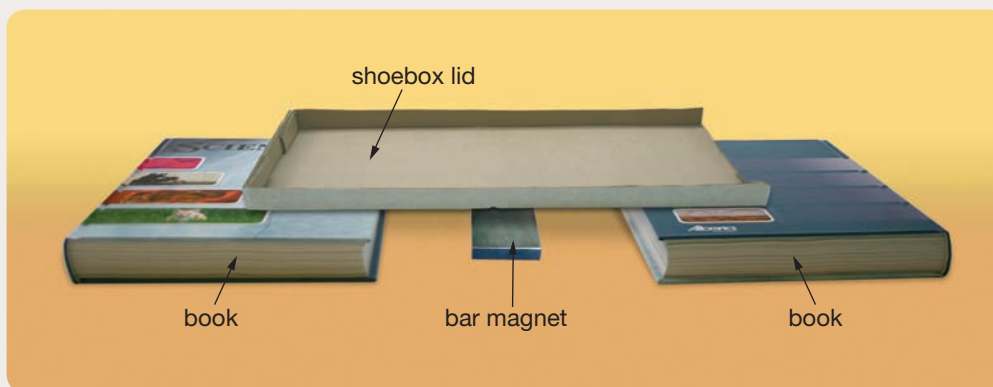


Figure C1.8

step 2: Observe the empty lid of the shoebox. Is there any evidence of a magnetic field being present?

step 3: Lightly sprinkle iron filings into the lid of the shoebox. Be careful not to allow any filings to spill outside the lid. Gently tap the tops of the two books with your fingers for a few seconds until the filings form a pattern.

step 4: Observe the pattern of filings from above. Sketch a diagram to record your observations.

step 5: Observe the filings by looking from the side, just over the edge of the shoebox. Sketch a diagram to record your observations.

step 6: Carefully pour the iron filings back into the container.



Science Skills

- ✓ Performing and Recording
- ✓ Analyzing and Interpreting



CAUTION!

Iron filings should be handled with care.

- If the filings come in contact with a magnet, they are very difficult to remove.
- If the filings come in contact with your clothing, permanent staining is a possibility.
- Avoid spills.

step 7: Set up the apparatus as shown in Figure C1.9, and repeat steps 3 to 6.

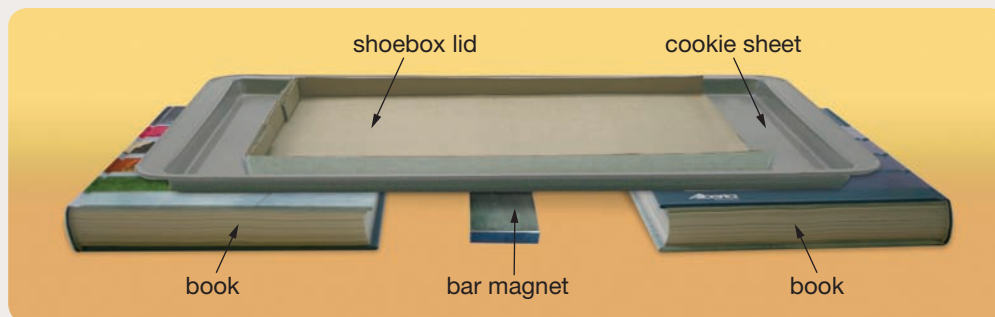


Figure C1.9

Analysis

1. Use your observations from step 2 to explain the importance of test bodies when observing magnetic fields.
2. Collect your observations from steps 4 and 5, when only the shoebox lid was between the magnet and the filings. Use these observations to answer the following questions.
 - a. Identify the regions of the magnet where the magnetic field lines are most concentrated.
 - b. Determine whether the magnetic field lines are restricted to the flat (two-dimensional) surface of the shoebox lid or whether they exist in the three-dimensional space beyond the shoebox lid.
3. Collect your observations from step 7, when both the cookie sheet and the shoebox lid were between the magnet and the filings. Use these observations to answer the questions 3.a. and 3.b.
 - a. Describe how the cookie sheet changed the pattern of filings.
 - b. Many sensitive electronic devices do not perform well if exposed to strong magnetic fields. Suggest a way to shield these devices from strong magnetic fields.

Part B: Using a Compass as a Test Body

Procedure and Observations

- step 1:** Check your compass to ensure that it points to magnetic north.
- step 2:** Obtain the handout “Placement of a Compass Around a Bar Magnet.” Note that the positions for the compass on this handout follow from the observations with the iron filings in Part A.
- step 3:** Position the bar magnet where shown on the handout, and place the compass at the other end of the table.
- step 4:** Working quickly and efficiently, momentarily place the compass in each of the positions shown on the handout. In each position, do the following:
- Observe which way the north end of the compass needle points.
 - Move the compass to the other end of the table.
 - Draw an arrow on the handout to record your results.

Analysis

4. Use your observations to determine which end of the magnet is the south end and which end is the north end.
5. In Part A you were able to observe the pattern formed by many field lines. In Part B you were able to observe the direction that the north end of a compass needle would point along two field lines. Combine your results from Parts A and B by producing a diagram that includes the direction of many field lines surrounding a magnet.



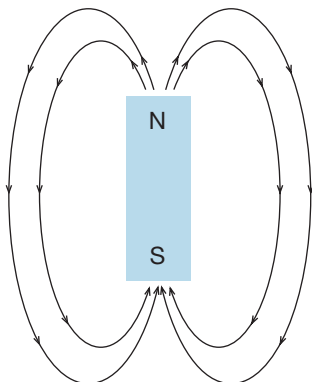
CAUTION!

The sensitive magnet in a compass needle is easily damaged if exposed to strong magnetic fields for an extended length of time.

- Do not store compasses in the same location as strong magnets.
- Do not allow compasses to touch strong magnets.
- If a procedure requires that a compass be momentarily brought close to a strong magnet, quickly make the observation and then return the compass to a safe distance from the magnet.

Key Ideas About Magnetic Fields

Magnetic field lines show the way the north end of a compass needle would point. These lines always leave the north end of a magnet and form a loop that enters the south end of a magnet. You can confirm your understanding of these ideas by using a computer simulation in the “Two Magnets” activity.



Utilizing Technology

Two Magnets



Science Skills

- ✓ Performing and Recording
- ✓ Analyzing and Interpreting

Purpose

You will use the computer simulation “Two Magnets” from the Science 30 Textbook CD to explore the pattern of magnetic field lines between two magnets.



Procedure

Follow the instructions in the computer simulation and complete the activity.

Summary

Record four statements to summarize what you have learned in this activity.

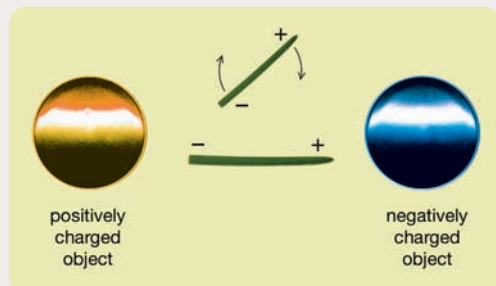
Investigation

Observing Electric Field Lines

Purpose

You will sketch the patterns produced by test bodies when they are placed in electric fields.

Background Information: Using Grass Seeds as Test Bodies



Science Skills

- ✓ Performing and Recording
- ✓ Analyzing and Interpreting



CAUTION!

This investigation requires the use of high-voltage devices to create the electric fields you will be studying. Be sure to follow all the recommendations of your teacher regarding the safe use of this equipment.

Although grass seeds are insulators, the small number of charges on the grass seed can be separated slightly. Grass seeds floating in mineral oil can be used to demonstrate the presence of electric fields. Because one end of a grass seed is slightly positive and the other is slightly negative, the seed will twist as each end is pulled in an opposite direction. The seed stops twisting when it is aligned with the electric field. Grass seeds that sink to the bottom of the mineral oil are not able to align with the electric field, so these should be ignored as you look for patterns.

Materials

- high-voltage DC power supply (at least 500 V DC)
(An inexpensive, handheld bug zapper can be modified to become a high-voltage power supply.)
- 200 mL of mineral oil
- latex or vinyl gloves
- waste bucket to recover mineral oil
- large Petri dish (100 mm by 15 mm)
- 10 mL of grass seed
- variety of objects to become charged in the Petri dish
 - straight-line sources ($\frac{1}{2}$ -inch copper plumbing tees)
 - point sources ($\frac{3}{4}$ -inch copper plumbing coupling)
 - variable-shaped sources (large hex nuts or eyebolts)
 - 2 strips of thin metal sheeting (2 cm by 15 cm each)
(inexpensive metal flashing used for roof repair)

Procedure

step 1: Put on the latex or vinyl gloves.

step 2: Pour mineral oil into the Petri dish until the layer of mineral oil is about 3 mm deep. Pouring slowly helps prevent bubbles.

step 3: Obtain the “Observing Electric Fields: Sources” handout from the Science 30 Textbook CD.



step 4: For the first arrangement of sources shown in the handout, do the following:

- Place the sources in the Petri dish as shown in the handout. Make sure the sources are no more than 2 cm apart.
- With the high-voltage power supply switched off, connect the sources.
- Switch on the high-voltage power supply. Before adding the grass seeds, observe the region between the sources for any evidence of an electric field.
- Carefully add a few grains of grass seed in the space between the sources.
- If you notice that the floating grass seeds are starting to line up in the mineral oil, add a few more grass seeds to the areas where the lines appear to be going.
- Once the pattern formed by the floating grass seed is visibly distinct, switch off the high-voltage power supply. It may help to form the pattern if you repeatedly switch the power supply on and off.
- Sketch the pattern of electric field lines shown by the floating grass seeds in the corresponding space on the handout.
- Remove the sources from the Petri dish. Carefully empty the mineral oil and grass seeds from the Petri dish into the empty waste bucket.

step 5: Repeat step 4 for each of the other sources on the “Observing Electric Fields: Sources” handout.

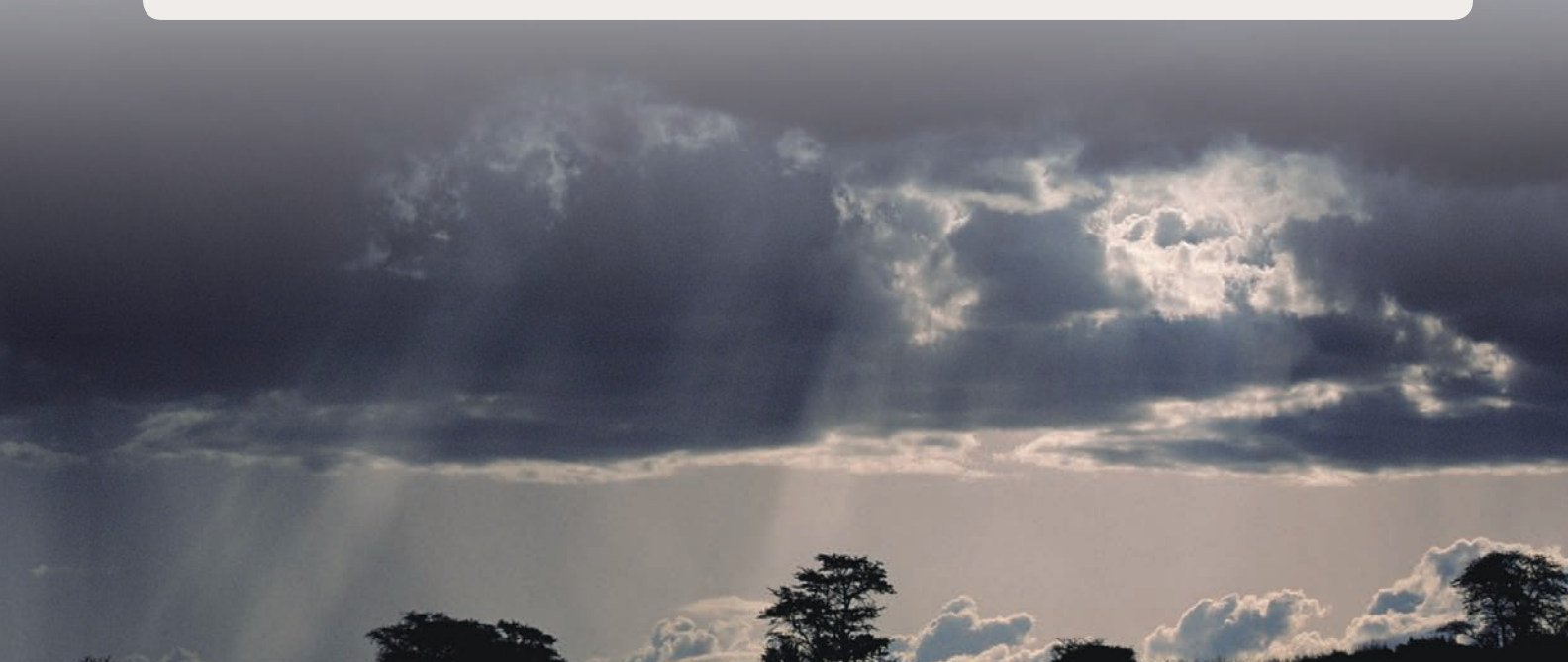
step 6: Obtain the “Observing Electric Fields: Lightning Safety” handout from the Science 30 textbook CD. Follow the instructions on this handout to bend the two metal strips into the required shapes.



step 7: Repeat step 4 using the metal shapes you created in step 6.

Analysis

1. Recall what you observed between the sources when the high-voltage power supply was turned on but the grass seed was not yet added. Explain the importance of test bodies when it comes to observing fields.
2. Identify the sources that tended to produce patterns of electric field lines that were evenly spaced. Which ones produced patterns that were concentrated?
3. Refer to your answer to question 2 and your observations from step 7. Use the patterns in the field lines to explain the safest location for hikers during a thunderstorm.



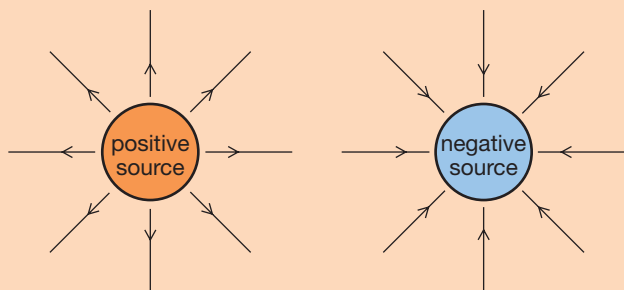
Adding Direction to Electric Field Lines

Although the grass seeds in the “Observing Electric Field Lines” activity provided an opportunity for you to sketch electric field lines, there was no way to indicate the direction in which the lines were pointing. The direction of an electric field is determined by the direction of the force on a positive test body. This is why electric field lines always point toward negative sources and away from positive sources—this is the way a positive test charge would go.

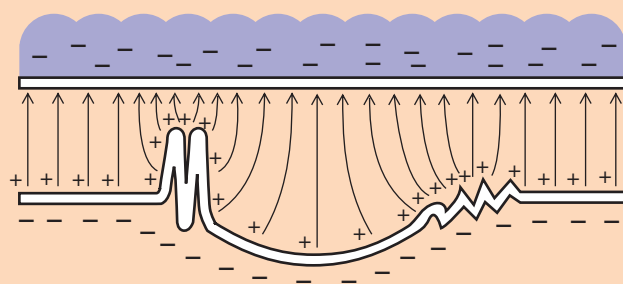
Under a typical thundercloud, the electric field can become very intense, especially around pointed objects that project high into the air. The electric field lines point up because this is the way that positive charges would move as they are attracted to negative charges in the cloud. Since the excess electrons in the bottom of the cloud are negatively charged, they move in the opposite direction to the electric field—down toward Earth’s surface.

Using this thinking, good advice to a hiker caught in a thunderstorm would be to seek a low region where the electric field lines are not as intense and, therefore, where the lightning is less likely to strike.

Direction of Electric Field Lines



Electric Field Lines Under a Thundercloud



1.1 Summary

Objects can become charged when electrons are transferred. Positively charged objects are the result of losing electrons, while negatively charged objects are the result of gaining electrons. Charge is measured in coulombs—a huge unit, since 1 C corresponds to a transfer of 6.25×10^{18} electrons. An uncomfortable spark from scuffing your feet across the carpet might be a few microcoulombs, while a single lightning strike could be 10 C to 30 C. Lightning is dangerous, not only because of the huge quantity of charge that is transferred, but also because this charge transfers incredible amounts of energy. The ratio of the change in electric potential energy to the charge transferred is called the potential difference or voltage and is measured in volts.

A field is an invisible connection between a source and a test body. The electric field that exists between the bottom of a thundercloud and the ground below can be detected by small charged objects below the cloud. The magnetic field produced by a strong magnet can be detected by another magnet, such as a compass needle. Gravitational fields produce noticeable effects on test bodies when the source is very massive—like a planet, a moon, or a star. Even though all of these fields are invisible, their effects on test bodies can be observed and recorded in field-line diagrams.

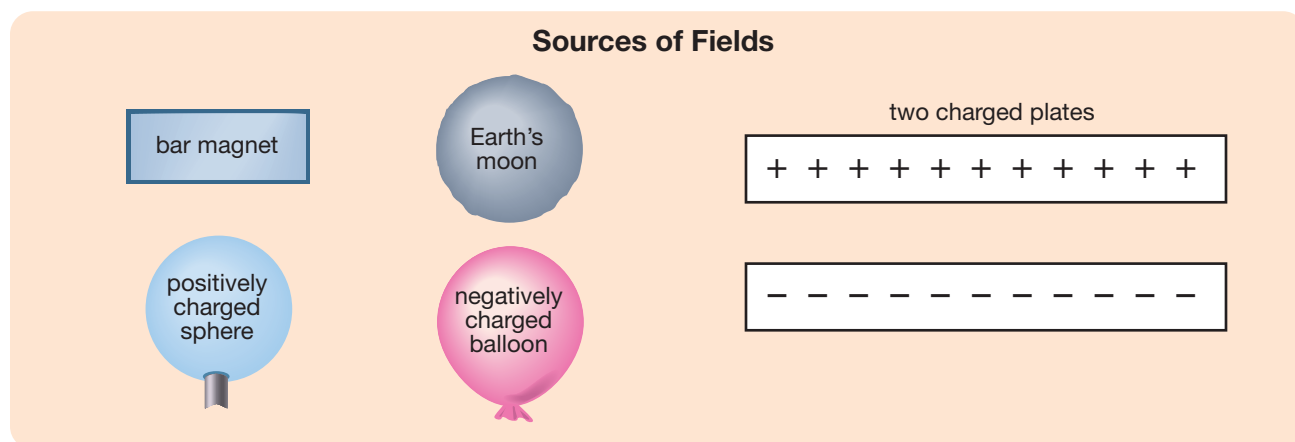
1.1 Questions

Knowledge

1. Define the following terms.
 - a. negative charge
 - b. positive charge
 - c. coulomb
 - d. electric potential difference
 - e. voltage
 - f. volt
 - g. electric field
 - h. magnetic field
 - i. gravitational field
 - j. test body
 - k. field lines
2. Compare and contrast characteristics of electric, magnetic, and gravitational fields.
3. Explain the importance of test bodies when studying fields.

Applying Concepts

4. Each of the following objects is the source of a field.



- Sketch each object in your notebook. Be sure to leave enough room to add the field lines.
- Under each of your sketches, identify the type of field you sketched.

Use the following information to answer question 5.

As a child goes down a plastic playground slide, the plastic surface tends to remove electrons from the child's clothing. When the child reaches the bottom of the slide, it is common for her to have developed enough charge to become the source of an electric field. Note the field lines indicated by the child's hair in the photograph. It is possible for children to acquire a voltage of over 20 000 V in these circumstances, creating a nasty shock when their feet touch the ground!

Many young children with impaired hearing use a special electronic device called a cochlear implant. The circuitry within these tiny devices is very sensitive to the buildup of static electricity on the user's body. Unfortunately, if a child using such a device slides down a plastic playground slide, the sudden discharge of static electricity at the bottom of the slide will often erase the specific programming on the microprocessor, causing the cochlear implant to fail.



- Determine whether the child became positively or negatively charged.
 - Sketch a field-line diagram to represent the electric field around the child's head.
 - The high voltage is sufficient to affect the circuitry in a cochlear implant. Beyond this effect, explain why the high voltage does not present a health hazard to most children who use the slide.